Climate Feedbacks

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Outline
- Stability/instability
- Feedbacks
- Examples
- Activity
Temperature and CO₂ concentration in the atmosphere over the past 400,000 years (from the Vostok ice core)

CO₂ concentration, ppmv

Year before present (present = 1950)

Temperature change from present, °C

Year before present (present = 1950)
Climate Feedbacks

- Earth/Atmosphere is **delicate balance**
  - incoming and outgoing radiation

- Slight changes in balance can cause
  - Large changes in global climate

- These changes can be *enhanced or diminished* by positive or negative feedbacks

- Positive feedback:
  - *initial change reinforced by another process.*

- Negative feedback:
  - *initial change counteracted by another process.*
Positive Feedbacks

- Processes that *accelerate* a change
  - Note: Feedbacks cannot *initiate* change; they can only alter the pace of change
- Important examples:
  - Ice-albedo feedback
  - Water-vapor feedback
The Earth’s climate is fairly stable in terms of temperature. This can be visualized using the following system diagram. The idea is that even though the system may change away from its initial point, it will have the tendency to go back to ‘normal’ eventually.
Stability versus instability

- **Stable:**
  - Given a perturbation, the system tends to return to original state

- **Instability:**
  - Given a perturbation, the system moves to another state.

Stable equilibrium

Unstable equilibrium
Multiple equilibrium

- The system may have multiple states of equilibrium

Stable to small perturbations
States of equilibrium

– The system may have multiple states of equilibrium

Stable to small perturbations, until a big force perturbs the system into a new equilibrium
Climate Stability

- The Earth’s climate changes as a result of internal/external forcing:
  - Changes in solar radiation
  - Changes in the earth’s orbit
  - Plate tectonics
  - Volcanoes
  - Human pollution etc.

- These forcings can be thought of as a perturbation (or push) to climate stability.

- These changes can be enhanced or diminished by positive or negative feedbacks
Climate Feedbacks

- Positive feedback:
  - *initial change reinforced by another process.*

- Negative feedback:
  - *initial change counteracted by another process.*

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Positive Feedbacks

- Processes that *accelerate* a change
  - Note: Feedbacks cannot *initiate* change; they can only alter the pace of change
- **Important climate examples:**
  - Ice-albedo feedback
  - Water-vapor feedback
  - Cloud feedback
Ice-Albedo Feedback (Cooling)

Initiating Mechanism:

Somehow this happens

Earth Cools

Ice Coverage Increases

Albedo Increases

Absorption of Sunlight Decreases

Positive Feedback
Fill in the blanks

Initiating Mechanism

1. increases, decreases, decreases
2. Decreases, decreases, increases
3. Increases, increases, increases
4. Decreases, decreases, decreases

Earth Warms

Ice Coverage ____________

Albedo ____________

Absorption of Sunlight ________

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**Ice-Albedo Feedback (Warming)**

- **Initiating Mechanism**
- Earth Warms
- Ice Coverage Decreases
- Albedo Decreases
- Absorption of Sunlight Increases

**Positive Feedback**
Fill in the blanks

1. Increases, increases, increases
2. Increases, decreases, decreases
3. Decreases, increases, increases
4. Decreases, decreases, decreases
Water Vapor Feedback (Warming)

Initiating Mechanism

Earth Warms

Evaporation Increases

Atmospheric Water Vapor Content Increases

Greenhouse Effect Strengthens

Positive Feedback
Water Vapor Feedback (Cooling)

Initiating Mechanism

Earth Cools

Evaporation Decreases

Atmospheric Water Vapor Content Decreases

Greenhouse Effect Weakens

Positive Feedback
Negative Feedbacks

- Processes that *reduce* an imposed change

- Important examples:
  - Cloud feedback
  - Chemical weathering

- *Note:* Positive/negative feedbacks have no relation to ‘good versus bad’, but are about how a system responds to a change.
Possible Role of Cloud in Warming or Cooling the Atmosphere

Figure 12.7 Role of cloud in both warming and cooling the atmosphere.
Which feedback is positive?

1. Left
2. Right

Figure 12.7 Role of cloud in both warming and cooling the atmosphere.
Activity

Imagine the Earth was to warm for some reason (initiating mechanism or perturbation)

A) Identify two positive feedbacks that would influence the earth’s climate and explain how each one works.

B) Identify two negative feedbacks that would influence the earth’s climate and explain how each one works.

C) Which feedback do you think is more uncertain. Explain your reasoning.
As a result of the earth’s warming over the last 100 years, plants have been growing at a faster rate. Because plants absorb CO2, the increase in plant growth means that more CO2 is being absorbed from the atmosphere by plants.

1. This is a positive feedback.
2. This is a negative feedback.
3. This has nothing to do with feedbacks.
Positive Feedback Exerted by Water Vapor in the Atmosphere

True or False?

Figure 12.6 Positive feedback exerted by water vapour (as a greenhouse gas) in the atmosphere.

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Positive Feedback Exerted by Snow and Ice

- Enhanced greenhouse warming
- Greater absorption of solar radiation
- Decreased albedo
- Melting of snow and ice

True or False?